EXPERIMENTAL CONTROL OF WEEDS IN SEED BED PREPARATION FOR PRAIRIE RESTORATION PLOTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

"It was more than 200 years ago that this first glimpse of Iowa was given to the world. No plow had ever turned a furrow on its virgin soil; the sound of firearms had never echoed among its groves and valleys. Its vast, natural meadows were covered with a carpet of waving grass, intermingled with myriads of brilliant wild flowers, radiant in the glow of a July sunlight. Nature here ruled supreme over the broad expanse of prairie..." This account of presettlement Iowa is given by Gue (1899).

However, in the same year Shambaugh (1899) writes "Vast prairies have been turned into innumerable farms. Corn, oats, wheat, rye, timothy and blue-grass have taken the place of wild vegetation ... Prairie chickens, quail, grouse and deer have disappeared ... Villages, towns and cities everywhere add to the evidence of a growing civilization."

In 1933 the state of Iowa, realizing the possible loss of all remnants of the prairie of presettlement Iowa, made provisions for the preservation of the remaining tracts of native prairie. These prairie remnants have since been extensively studied. Brotherson (1969) reports that "... recent studies, present ecological and taxonomic descriptions of four state-owned native prairie tracts. All accounts contain extensive reviews of prairie literature. The studies also include information on soils, micro-climate, topography, and management."

Recently the trend has been to produce new prairie through restoration. Research in this area has been reported by Christiansen and Landers (1966), Christiansen (1967), and Anderson (1970). Prairie is now being considered as landscape for residential, public and industrial buildings; roadside management for our highways (Landers and Kowalski, 1968); erosion control and reclaiming of waste land; and for the education of students and the general public about the prairie of presettlement Iowa.

Prairie restoration involves a variety of problems of which many are related to the germination of the native plant seed and the establishment of the native plants. The studies of germination and establishment under various conditions indicate the principle problem of establishment is the early growing season competition of weedy forbs and grasses. The competition from established perennial and annual weedy grasses and forbs was reported to be detrimental to the vigor and establishment of prairie grasses by Robocker and Miller (1955). Christiansen (1967) states that plots kept weed-free produced the largest percentage of establishment. Christiansen and Landers (1966) found similar results with the weed-free treatment favoring highest germination and establishment.

Prairie management generally incorporates mowing, burning, cultivation and chemical treatment to control the growth of weedy grasses and forbs. Weaver (1954) discussed the effects of the management techniques for controlling weeds on the individual species of the prairie and the total composition of the prairie, concluding that eradication of competing weeds was beneficial to the native plants.

Mowing of mature native plants was studied by Hayden and Aikman (1949). Their conclusion was that annual mowing had no harmful effects. However, the research by Robocker and Miller (1955) indicated that mowing had generally adverse affects on tall growing native grasses, affecting the individual species according to the growth stage of the plant and the frequency of mowing. Similar opinions of the detrimental affect of mowing to tall prairie grasses were given by Landers and Kowalski (1968).

Burning is a controversial method employed in prairie management. Its beneficial effects have been questioned by many researchers, thus the literature concerning burning as a management tool displays a variety of viewpoints. Robocker and Miller (1955) said burning appeared to be injurious to some prairie grasses and beneficial to others, depending on the stage of growth of the individual species. Favoring burning as a management tool, Kucera and Ehrenreich (1962) found a marked increase in growth of plants in experimental plots that had been burned. Hadley and Kieckhefer (1963) expressed the need for frequent fires as an important tool in the management of prairie.

Cultivation destroys established weedy grasses and forbs, prevents the growth of weed seedlings, and hinders germination of viable weed seed. Roberts (1963) concluded that the type of primary cultivation employed is relatively unimportant so far as the population of viable weed seeds in the soil is concerned.

Herbicides are used extensively in land management to control the growth of weeds. Treatment of an area with an herbicide or soil sterilant has become less desirable as their harmful residual effect on the flora and fauna of the prairie has become known. Landers and Kowalski (1968) reported that herbicides often instead of eliminating weeds, created disturbances which perpetuated them. Similarly, it was found that herbicides often destroyed the natural vegetation and encouraged the growth of noxious weeds (Anderson, 1970). Thus the sensitivity of native plants to herbicides and soil sterilants has limited their use to the control of specific species of weeds.

The previously mentioned techniques for weed control in well established prairies have been extensively studied. However, their application to the control of weeds in land prepared for the germination and establishment of native plants has received negligible attention.

The purpose of this study was to compare cultivation, burning and herbicide as methods of weed control in seed beds prepared for the germination and establishment of Big Bluestem (*Andropogon gerardi*),, Little Bluestem (*Andropogon scoparius*), Side-oats Grama (*Bouteloua curtipendula*), Switchgrass (Panicum virgatum), and Indian Grass (Sorghastrum nutans).

METHODS AND MATERIALS

The experimental site used in this study was located in Polk County, Iowa, Webster township (T. 79N. and R. 25W.), approximately three-fourths of a mile north of 7500 Meredith Drive, Urbandale, Iowa. The site was a ten acre abandoned pasture purchased by the Urbandale Park Board and intended for a public park to be opened in 1980. This pasture was cultivated before 1960 and more recently has been intermittently grazed by livestock.

A survey of the vegetation revealed the pasture to be predominantly a mixture of grasses. This mixture included smooth brome grass (Bromus inermis), barnyard grass (Echinochloa pungens), foxtail grass (Setaria viridis L. and Setaria glauca), stink grass (Eragrostia megastachya), and blue grass (Poa pratensis). Weedy forbs identified were velvetleaf (Abutilon theophrasti), common milkweed (Asclepias syriaca), wild morning glory (Convolvulus sepium), Canadian thistle (Cirsium arvense) carpet weed (Mollugo verticillata), purple alfalfa (Medicago sativa), red clover (Trifoluim pratense), common ragweed (Ambrosia elatior), and cockle bur (Xanthium strumarium). The plants were classified to genus according to Hitchcock (1968), Isely (1962), and Muenscher (1960).

A level portion with a slight slope to the east, in the north-east corner of the pasture was selected for the experimental site. The United States Department of Agriculture's soil survey of Polk County in 1957 indicated the soil to be Webster silty clay loam of Cary Glacial till origin.

An analysis of the soil of the plot indicated it to have a neutral pH and was low in available phosphate and potash (Soils Testing Laboratory Iowa State University, Ames, Iowa, 1970). The phosphate and potash were lower than desirable for the growth of prairie grasses; however, application of commercial fertilizer was avoided to prevent introduction of another variable to the experiment.

Table 1. The pH and nutrient determinations on soil from plots 1-8 before application of herbicide *

Plots	Depth in inches	pH	Available P_2O_5 (Phosphorus) lbs. / acre	Available K_2O (Potash) lbs. / acre
1 and 5	6	7.0	10	132
2 and 6	6	7.1	8	294
3 and 7	6	7.1	7	191
4 and 8	6	7.05	7	232

*These determinations were made by the Soils Testing Laboratory Iowa State University, Ames, Iowa.

The experimental site was 80 feet by 40 feet, subdivided into eight plots (Fig. 1), each plot measuring 20 feet by 15 feet. A longitudinal strip ten feet wide was left fallow to separate plots 1, 2, 3, and 4 from 5, 6, 7, and 8. The fallow strip served as a buffer zone to prevent the movement of the herbicide into adjacent plots through translocation.

On April 25, 1970, a tractor with a standard two furrow plow made a five foot strip around the experimental area. This border around the experimental site was kept weed-free throughout the summer as a buffer zone to restrict the movement of weedy plants into the experimental site from the adjacent pasture. The initial vegetation of plots 1, 2, 5, and 6 was burned completely requiring less than one-half hour. Plots 1 and 5 were plowed immediately after the fire subsided.

In May, the entire plowed area, including the border, was disked using a tractor and standard cultivation disk (Fig. 2). Two days later the disked area was roto-tilled with a hand operated heavy-duty roto-tiller. Any remaining large clumps of weeds or grass root masses were weeded out by hand.

Five weeks later plots 2 and 6 showed a substantial re-growth of the blue grass sod which contained an occasional clump of purple alfalfa (Fig. 3). Plots 1 and 5 (Fig. 4) and plots 3 and 7 (Fig. 5) showed only a slight new growth of

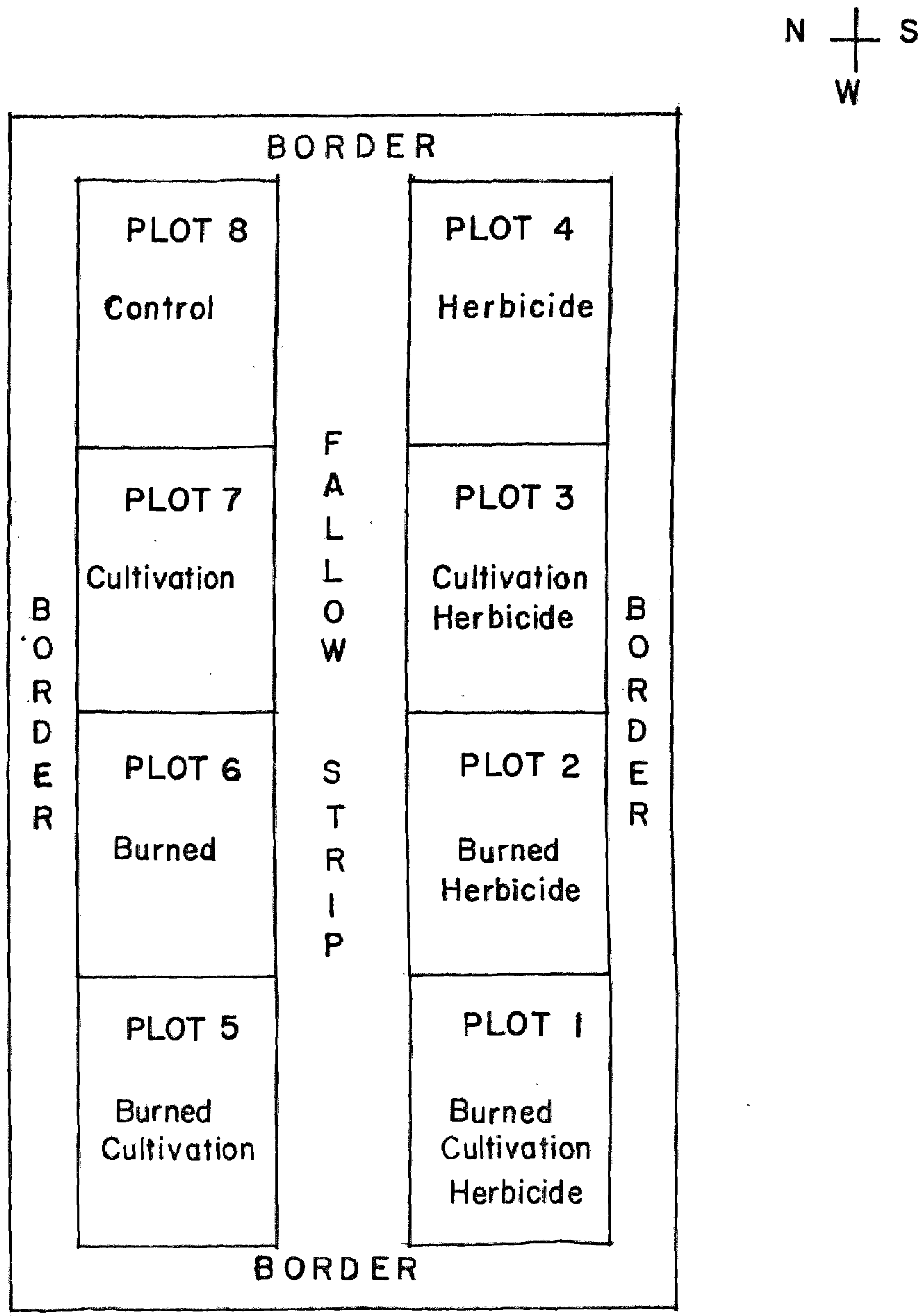


FIGURE I. Experimental plots, showing method of weed control used in the individual seed-bed plots. Scale: 2/5"=5'.

Figure 2. View of entire experimental area. The plot in the foreground is burned-cultivated. Burned, cultivated, and undisturbed plots appear in that order in the background. May 1970.

Figure 3. Plots 2 and 6 exhibited abundant growth of Poa pratensis two weeks after burning. May 1970.

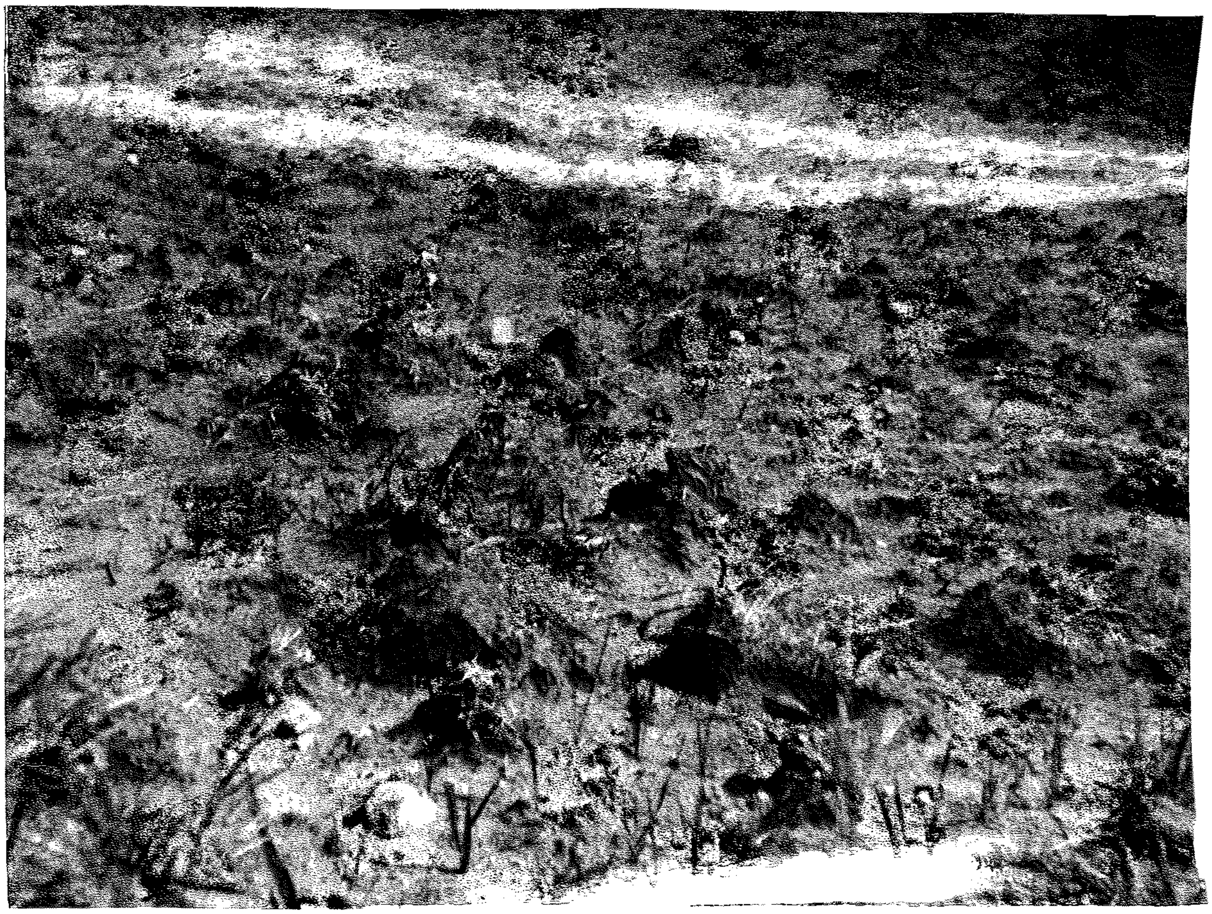


Figure 4. Plots 1 and 5 after burning and cultivation with a standard disk. May 1970.

Figure 5. Plots 3 and 7 after cultivation with a standard disk. May 1970.

weedy forbs and grasses from seed which germinated after cultivation. Plots 4 and 8 (Fig. 6) which were undisturbed, had an abundance of brome grass in full bloom. This existing vegetation was destroyed in plots 1, 3, 5, and 6, and in the border by roto-tilling with a small hand operated garden roto-tiller.

A general herbicide, Ammonium Sulphamate (Ammate), purchased from the Fisher Chemical Company was selected for its properties of being non-toxic to soil microorganisms and fauna (Smith, Dawson, Wenzel, 1945), non-residual in the soil, effective against the vegetation for a month and then rapidly leaching out of the soil (Petersen and Petersen, 1960). These properties insure destruction of the weedy vegetation with suitable time in the growing season remaining to allow the prairie grass seed to germinate and become established.

A solution of one pound of ammonium sulphamate per one gallon of tap water (I.S.U. Cooperative Extension Service, 1964) was prepared and applied with a three-gallon hand vacuum pump sprayer on July 10th to plots 1, 2, 3, and 4 at the rate of one and one-fourth gallons per 300 square feet. Five days later the ammonium sulphamate had destroyed the weedy forbs and the above-ground structures of the grass plants (Fig. 7, 8, 9, 10).

Plots 2, 3, 5, and 7 were hand-raked to loosen the soil on July 15, 1970. The seed of Big Bluestem (<u>Andropogon</u>

Figure 6. Plots 4 and 8 exhibit Bromus inermis, the dominant grass of these plots, in full bloom. May 1970.

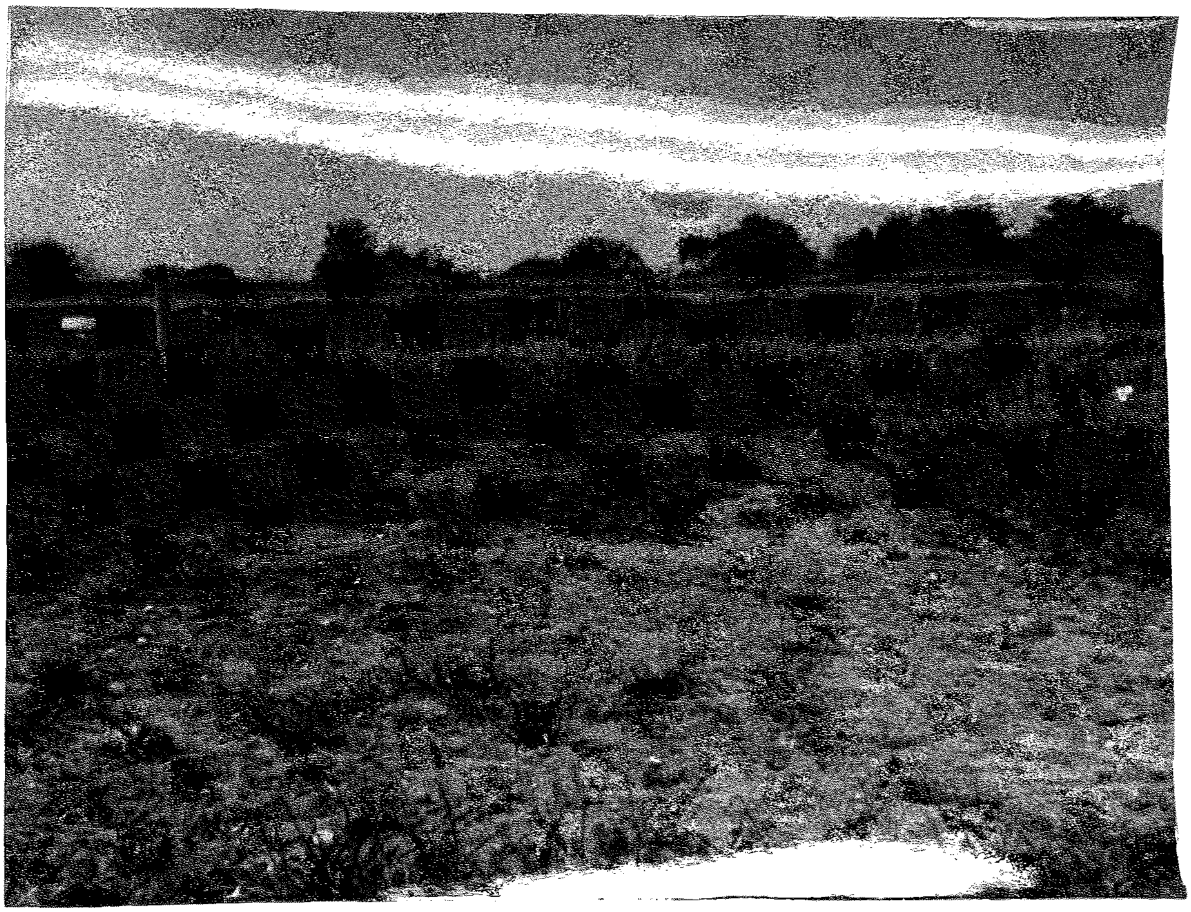


Figure 7. In the foreground is plot 1 after the application of ammonium sulphamate. Plot 5 in the background did not receive chemical treatment. June 1970.

Figure 8. In the foreground is plot 2 after the application of ammonium sulphamate. Plot 6 in the background did not receive chemical treatment. June 1970.

Figure 9. In the foreground is plot 3 after the application of ammonium sulphamate. Plot 7 in the background did not receive chemical treatment. June 1970.

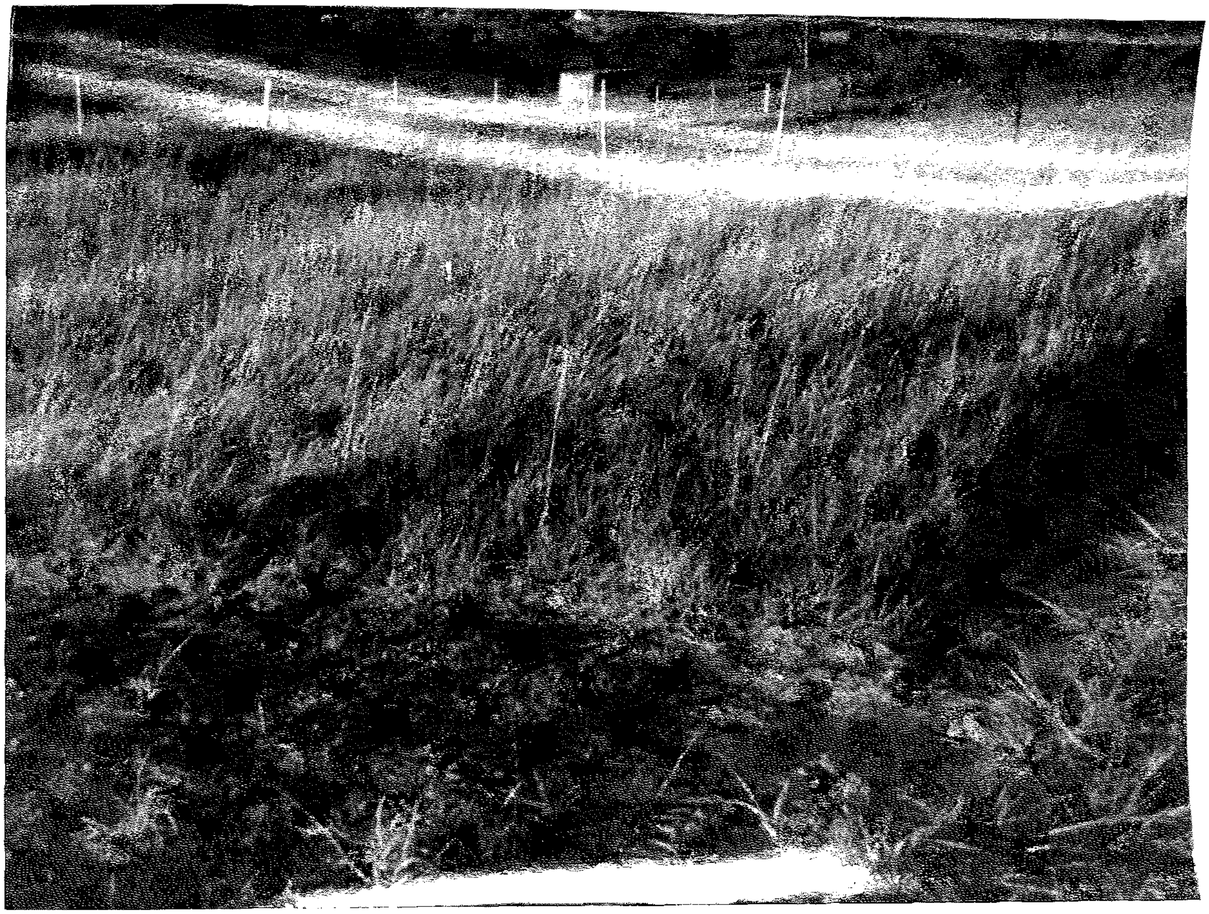


Figure 10. In the foreground is plot 4 after the application of ammonium sulphamate. Plot 8 in the background to the left of plot 4 did not receive chemical treatment. June 1970.

gerardi), Little Bluestem (Andropogon scoparius), Side-oats Grama (Bouteloua curtipendula), Switchgrass (Panicum virgatum), and Indian Grass (Sorghastrum nutans) for each plot was weighed, mixed by vigorous shaking in a paper bag for several minutes, and sown by broadcasting (Landers, 1970) at a rate of 207 grams per 300 square feet. This weight of weed contains approximately 211 live seeds per square foot divided among the five species of prairie grass (Wilson Seed Farms, 1970). A hand rake was used to cover the seed with approximately one-half inch of soil.

A small plot of ground at 7501 Meredith Drive, Urbandale, Iowa, was prepared in a corner of a cultivated field of Webster silty clay loam, approximately one mile from the experimental site. An amount of seed equal to that used for each experimental plot was broadcast and covered with soil. This plot was artificially watered and hand weeded to ensure growth of the grass seedlings. The grass seedlings from this plot (3 to 10 inches in height) were removed and mounted on herbarium sheets in October. The herbarium sheets were used for field identification.

In October the individual experimental plots were sampled. The quadrat-frequency technique was used for sampling the experimental plots (Fig. 11). The south edge of plots 1, 2, 3, and 4 and the north edge of plots 5, 6, 7, and 8 were used as baselines. One perpendicular transect line was placed every four feet along the baseline, with each plot having five transects. Seven quadrats were placed one foot apart along each 15 foot transect. The first quadrat of each transect was placed of the transect with restricted randomization. The quadrat was placed at the base-line on the first transect, ½ foot from the base-line on the second transect, 1 foot from the base-line on the third transect, at the base-line on the fourth transect, and ½ foot from the base-line on the fifth transect. This pattern was repeated for the placing of the quadrats in each plot sampled.

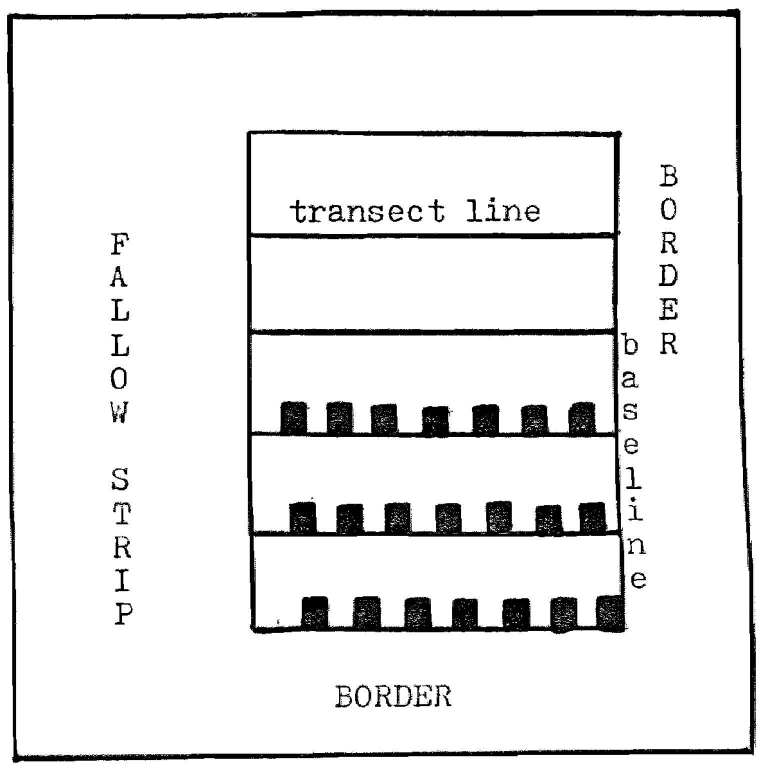


Figure 11. Experimental plot showing the technique used for sampling. One foot square quadrats (■) were placed along the transect line at one foot intervals beginning either at the base-line, ½ foot from the base-line, or 1 foot from the base-line. (Scale: 1/8 inch = 1 foot)

Studies by Wiegart (1962), Van Dyne, Vogel, and Fisser (1963), and Hyder, Conrad, Tueller, Calvin, Poulton and Sneva (1963) indicated that the one-foot square quadrat is the optimum size for the type of vegetation in the experimental area. Only species of the five prairie grasses present within the quadrat (the center of the plant or half of its area) are recorded. The five species of grasses were identified according to Weaver (1954) and Hitchcock (1968). The herbarium sheets with specimens from the plot at 7501 Meredith Drive of Andropogon gerardi, Andropogon scoparius, Bouteloua curtipendula, Panicum virgatum, and Sorghastrum nutans were used for comparison when necessary.

An analysis of variance test was used to determine if the method of weed control or the interaction between methods of weed control produced significant differences in the amount of germination and establishment of five prairie grass species. The analysis of variance was used specifically to determine the significance of the number of plants between the plots and within the plots (Snedecor and Cochran, 1967).

RESULTS

In October 1970, the experimental plots, located three-fourths of a mile north of 7500 Meredith Drive in Urbandale, were sampled. Thirty-five foot square quadrats were randomly placed along transect lines in each plot. The number of the five species of prairie grass found within the thirty-five quadrats placed in each plot was recorded. The data collected indicated the number of the five species of prairie grass plants which germinated under the conditions of seven different weed control treatments. An analysis of variance test was used to measure any difference between the number of plants in experimental plots as compared to the control plot, and the number of plants within the experimental plots as compared one to another (Table 2).

The F-value was subsequently determined at a significant level of .01, using 1 as the degree of freedom for the greater mean square and 272 (interpolated between 200 and 400) as the degree of freedom for the smaller mean square. The significant F-value was calculated to be 3.88 (Snedecor and Cochran, 1967). Table 3 illustrates that the control or elimination of weedy plants was highly significant. The herbicide treatment was the only method of weed control which did not produce significant results at the .01 level. The F-value for the remaining treatments were all significant.

The analysis of variance test (Table 4) indicated that cultivation was the most significant method of weed control for the five species of grass. Each species responded more to this single treatment than to any other single treatment or interaction between treatments. It is also meaningful to mention that when a significant response to the herbicide occurred, the interaction between cultivation and the herbicide was also significant. This relationship is due to the

Table 2. The total number of *Andropogon gerardi*, *Andropogon scoparius*, *Bouteloua curtipendula*, *Panicum virgatum*, *Sorghastrum nutans* counted in the thirty-five foot-square samples taken in each experimental plot and the control plot

treatment		A.g.	A.s.	B.c.	P.v.	S.g.
A	(Cultivation)	2	80	34	47	99
B	(Burning)	0	0	0	0	0
C	(Herbicide)	0	1	1	0	1
AB	(interaction)	15	148	201	160	123
AC	(interaction)	15	7	82	157	27
BC	(interaction)	8	22	17	15	16
ABC	(interaction)	10	13	135	93	29
none	(control plot)	0	0	0	0	0
Total		50	271	470	472	295

Table 3. The F-values of the experiment on weed control for *Andropogon gerardi*, *Andropogon scoparius*, *Bouteloua curtipendula*, *Panicum virgatum*, and *Sorghastrum nutans* *

treatment**	A.g.	A.s.	B.c.	P.v.	S.n.	all species
A	13.41^{+}	59.08^{+}	73.28^{+}	51.53^{+}	82.19^{+}	115.49^{+}
B	03.55^{-}	10.53^{+}	21.67^{+}	01.01^{-}	02.03^{-}	11.70^{+}
C	02.76^{-}	39.94^{+}	00.00^{-}	00.94^{-}	26.75^{+}	03.73^{-}
AB	00.00^{-}	03.28^{-}	16.19^{+}	00.27^{-}	00.15^{-}	05.10^{+}
AC	00.00^{-}	62.28^{+}	00.50^{-}	00.23^{-}	40.41^{+}	10.17^{+}
BC	01.00^{-}	01.96^{-}	03.74^{-}	06.92^{+}	00.06^{-}	05.67^{+}
ABC	07.69^{+}	08.04^{+}	06.57^{+}	09.72^{+}	01.65^{-}	12.57^{+}

* the significant F-value at the .01 level was 3.88. The + indicates a significant F-value, and the - indicates a non-significant F-value.

** A represents cultivation
B represents burning
C represents herbicide application
AB, AC, BC, and ABC represent interaction of the above.

Table 4. Analysis of variance of weed control experiment on the number of *Andropogon gerardi*, *Andropogon scoparius*, *Bouteloua curtipendula*, *Panicum virgatum*, and *Sorghastrum nutans* plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	6850.80	1	6850.80	115.49**
B (Burning)	694.57	1	694.57	11.70**
C (Herbicide)	221.43	1	221.43	3.73
AB (interaction)	302.43	1	302.43	5.10**
AC (interaction)	603.29	1	603.29	10.17**
BC (interaction)	336.60	1	336.60	5.67**
ABC (interaction)	745.89	1	745.89	12.57**
Error	16134.80	272	59.32	
Total	25889.82	279		

** Significant F-value at the .01 level is 3.88.

cultivation increasing the effectiveness of the chemical action of the herbicide.

Burning was the other significant single method of weed control. Two species, Andropogon scoparius and Bouteloua curtipendula responded significantly to this method.

The herbicide treatment did not produce significant results (F-value, 3.73) when considering the total effectiveness for the five species (Fig. 12). However, Andropogon scoparius and Sorghastrum nutans did give significant response to this treatment. The lack of significant results may be due to the ability of the herbicide to increase the dormancy of seeds, consequently inhibiting the germination of the prairie grass seed (Audus, 1964).

The interaction between cultivation and burning produced significant results as a method of weed control. Bouteloua curtipendula responded well to this interaction. This was expected since this species responded to both cultivation and burning as single treatments. Andropogon scoparius showed a response to this interaction treatment, however, the F-value of 3.28 was not significant.

The interaction between cultivation and the herbicide (Fig. 13) was the most significant of the interactions between the two methods of weed control. Andropogon scoparius and Sorghastrum nutans responded significantly to this treatment. They also responded to cultivation and the herbicide as single treatments. The response to the

Figure 12. Plot 4 in the foreground exhibits a reduction in the growth of <u>Bromus inermis</u>, established in this plot. Plot 8 in the background contains an abundant growth of <u>Bromus inermis</u>. October 1970.

Figure 13. Plot 3 in the foreground exhibits a severe reduction in the growth of weedy grasses and forbs. Plot 7 in the background contains an abundant growth of Setaria viridis L., Setaria glauca, and other weedy plants. October 1970.

interaction did not surpass the response to cultivation, but did surpass the response to the herbicide.

The interaction between burning and the herbicide produced significant results (Fig. 14). Panicum virgatum responded to this treatment while not responding to either burning or the herbicide as single treatments. This was perhaps due to the destruction of the vegetation by burning thus improving the effectiveness of the herbicide as a soil sterilant.

Next to cultivation, a single method of weed control, the most significant results were produced by the interaction between cultivation, burning, and the herbicide (Fig. 15). Sorghastrum nutans was the only species to not respond significantly to this treatment. This species did not respond significantly to burning or to any interaction involving burning. Consequently, burning may have been the factor that lowered its response to the interaction of the three treatments.

The number of plants counted in each experimental plot was used to estimate the percentage of germination of each of the five species of prairie grass (Table 5). The number of live seed of each species of grass per gram per square foot sown was determined to be: Andropogon gerardi - 12.0, Andropogon scoparius - 58.7, Bouteloua curtipendula - 64.3, Panicum virgatum - 39.9, Sorghastrum nutans - 36.8 (Wilson Seed Farms, 1970). The average number of plants

Figure 14. Plot 2 in the foreground exhibits reduction in the growth *Poa pratensis* established in this plot, and other weedy plants. Plot 6 in the background is predominantly *Poa pratensis*. October 1970.

Figure 15. Plot 1 in foreground exhibits reduction in growth of weedy grasses and forbs. Plot 5 in background contains abundant growth of Setaria viridis L., Setaria glauca, and other weedy plants. October 1970.

counted per square foot was divided into the average number of live seeds per square foot to find the percentage of germination. This estimated percentage of germination for each species indicated that they responded individually to the method of weed control used.

Table 5. The estimated percentage of germination of Andropogon gerardi, Andropogon scoparius, Bouteloua curtipendula, Panicum virgatum, and Sorghastrum nutans during the 1970 growing season.*

treatment	A.g.	A.s.	B.c.	P.v.	S.g.
A (Cultivation)	00.5	03.9	02.6	02.1	07.1
B (Burning)	00.0	00.0	00.0	00.0	00.0
C (Herbicide)	00.0	00.1	00.1	00.0	00.1
AB (interaction)	03.6	07.2	15.6	07.1	08.9
AC (interaction)	03.6	03.4	06.4	07.0	01.9
BC (interaction)	01.9	01.1	01.3	06.7	01.1
ABC (interaction)	02.4	00.6	10.5	04.1	02.1

* Based on the percentage of pure live seed per gram weight (Wilson Seed Farm, Polk, Nebraska, 1970).

An analysis of variance test performed on the data determined a significant interaction existed between the method of weed control and the species of grass (Table 6). The F-value for the method of treatment and for the species of grass was considered significant at the .01 level. The value of F for the interaction between the method of treatment and the species of grass was 6.77, 1.74 considered significant at the .01 level.

Table 6. Analysis of variance of weed control experiment on the interaction between the method of weed control and the species of plant

Variation	Sum of Squares	DF	Mean Square	F
A (treatment)	2002.09	7	286.01	49.22**
B (species of grass)	434.65	4	108.66	18.72**
AB (interaction)	1102.43	28	39.37	6.77**
Error	7898.23	1360	5.81	
Total	11437.39	1399		

** Significant F-value at the .01 level for A is 2.66, B is 2.38 and AB is 1.74.

The results of the analysis of variance test measuring the significant interaction of the individual species of grass to the various methods for weed control is given in Tables 7, 8, 9, 10, and 11. The F-values calculated from this data were given in Table 3. The significant F-value at the .01 level for Table 3 is 3.88. The results given in each of these tables will be considered individually.

Andropogon gerardi responded to cultivation (Table 7). The species also responded significantly to the interaction treatment of cultivation, burning, and herbicide application.

Table 7. Analysis of variance of weed control experiment on the number of Andropogon gerardi plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	3.89	1	3.89	13.41**
B (Burning)	1.03	1	1.03	3.55
C (Herbicide)	0.80	1	0.80	2.76
AB (interaction)	0.00	1	0.00	0.00
AC (interaction)	0.00	1	0.00	0.00
BC (interaction)	0.29	1	0.29	1.00
ABC (interaction)	2.23	1	2.23	7.69**
Error	80.17	272		
Total	88.42	279		

** Significant F-value at the .01 level is 3.88.

Andropogon scoparius was the most successful in the rate of germination (Table 5). This species responded significantly to the three basic methods of weed control; cultivation, burning, and herbicide (Table 8). Significant results occurred from the interaction between cultivation and herbicide application, and the interaction between cultivation, burning, and herbicide application.

Table 8. Analysis of variance of weed control experiment on the number of *Andropogon scoparius* plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	180.80	1	180.80	59.08**
B (Burning)	32.23	1	32.23	10.53**
C (herbicide)	122.23	1	122.23	39.94**
AB (interaction)	10.03	1	10.03	3.28
AC (interaction)	190.57	1	190.57	62.28**
BC (interaction)	6.00	1	6.00	1.96
ABC (interaction)	24.60	1	24.60	8.04**
Error	832.23	272	3.06	
Total	1398.71	279		

** Significant F-value at the .01 level is 3.88.

The analysis of the data for Bouteloua curtipendula indicated that this species responded very significantly to cultivation, burning, and the interaction between cultivation and burning (Table 9). The species also responded significantly to the interaction of cultivation, burning and herbicide application. The F-value for the interaction of burning and herbicide application was 3.74, which is not significant, but worthy of mention. Because this species did not respond significantly to herbicide application, this F-value may be due primarily to the influence of burning upon the species.

Table 9. Analysis of variance of weed control experiment on the number of Bouteloua curtipendula plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	672.70	1	672.70	73.28**
B (Burning)	198.91	1	198.91	21.67**
C (Herbicide)	0.00	1	0.00	0.00
AB (interaction)	148.63	1	148.63	16.19**
AC (interaction)	4.63	1	4.63	0.50
BC (interaction)	34.30	1	34.30	3.74
ABC (interaction)	60.36	1	60.36	6.57**
Error	2497.54	272	9.18	
Total	3617.07	279		

** Significant F-value at the .01 level is 3.88.

Panicum virgatum responded significantly to cultivation, the interaction between burning and herbicide application, and the interaction between cultivation, burning, and herbicide application (Table 10).

Table 10. Analysis of variance of weed control experiment on the number of *Panicum virgatum* plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	697.73	1	697.73	51.53**
B (Burning)	13.73	1	13.73	1.01
C (Herbicide)	12.86	1	12.86	0.94
AB (interaction)	3.66	1	3.66	0.27
AC (interaction)	3.21	1	3.21	0.23
BC (interaction)	93.73	1	93.73	6.92**
ABC (interaction)	131.66	1	131.66	9.72**
Error	3683.77	272	13.54	
Total	4640.34	279		

** Significant F-value at the .01 level is 3.88.

The results of the analysis of the data for *Sorghastrum nutans* indicated that this species gave a very significant response to cultivation and to the herbicide application. Significant response to the interaction between cultivation and herbicide application was also demonstrated. This species did not seem to respond to burning or any interaction that included burning (Table 11).

Table 11. Analysis of variance of weed control experiment on the number of *Sorghastrum nutans* plants

Variation	Sum of Squares	DF	Mean Square	F
A (Cultivation)	243.29	1	243.29	82.19**
B (Burning)	6.00	1	6.00	2.03
C (Herbicide)	79.29	1	79.29	26.75**
AB (interaction)	0.43	1	0.43	0.15
AC (interaction)	119.60	1	119.60	40.41**
BC (interaction)	0.17	1	0.17	0.06
ABC (interaction)	4.89	1	4.89	1.65
Error	804.51	272	2.96	
Total	1258.20	279		

** Significant F-value at the .01 level is 3.88.

The treatments when ranked according to the degree of significant results (effective weed control) occur in the following order: 1) cultivation, 2) cultivation, burning, and herbicide, 3) burning, 4) cultivation and herbicide, 5) burning and herbicide, 6) cultivation and burning, 7) herbicide.

DISCUSSION

This study provides data that reinforces the concept that native prairie plants germinate and establish themselves more successfully in a weed-free environment.

All of the methods employed to control weeds in the seedbeds, with the exception of the herbicide, produced results significant enough to warrant their consideration for use when preparing ground for the planting of prairie grass seed.

Cultivation was the single most important factor in the control of weeds and the successful establishment of the grass seedlings. In October, at the end of the growing season, the prairie grasses were found primarily in the four plots that had been cultivated.

The effectiveness of cultivation was due to three factors. The first factor was the depth to which the soil was plowed. Roberts (1963) found that if weed seed production is continuous, a build up of a high population of some weed seeds will occur less rapidly with plowing. If the weed seed is buried to a depth of 6-8 inches, it loses its viability. Mayer and Poljakoff-Mayer (1963) state that weed seeds not damaged by plowing will germinate rapidly with adequate water, gases, temperature, and light.

The use of rotary cultivation to destroy the weed seedlings produced from the germination of viable weed seeds is also of importance. The foxtail grasses re-established themselves by the fall of the first growing season in the experimental plots which were cultivated only twice with the roto-tiller. This might have been prevented by cultivating the soil with the roto-tiller four times throughout the spring as recommended to control weedy foxtail and barnyard grass (Wilson, 1970).

A third important factor in the establishment of prairie plant seedling was the disturbance or destruction of the established Poa pratensis and Bromus inermis sod. Christiansen (1967) found that when the prairie plants were placed in competition with such vigorous perennial species as Bromus inermis, they were at a distinct disadvantage. Moyer (1953) felt that the Poa pratensis was not as great a threat since it did not establish a sod to the exclusion of the native prairie plants. However, the drastic reduction in the weedy competitors for light, moisture, gases and soil nutrients, by destroying these two sod-forming grasses is crucial for a high percentage of establishment of the prairie plants.

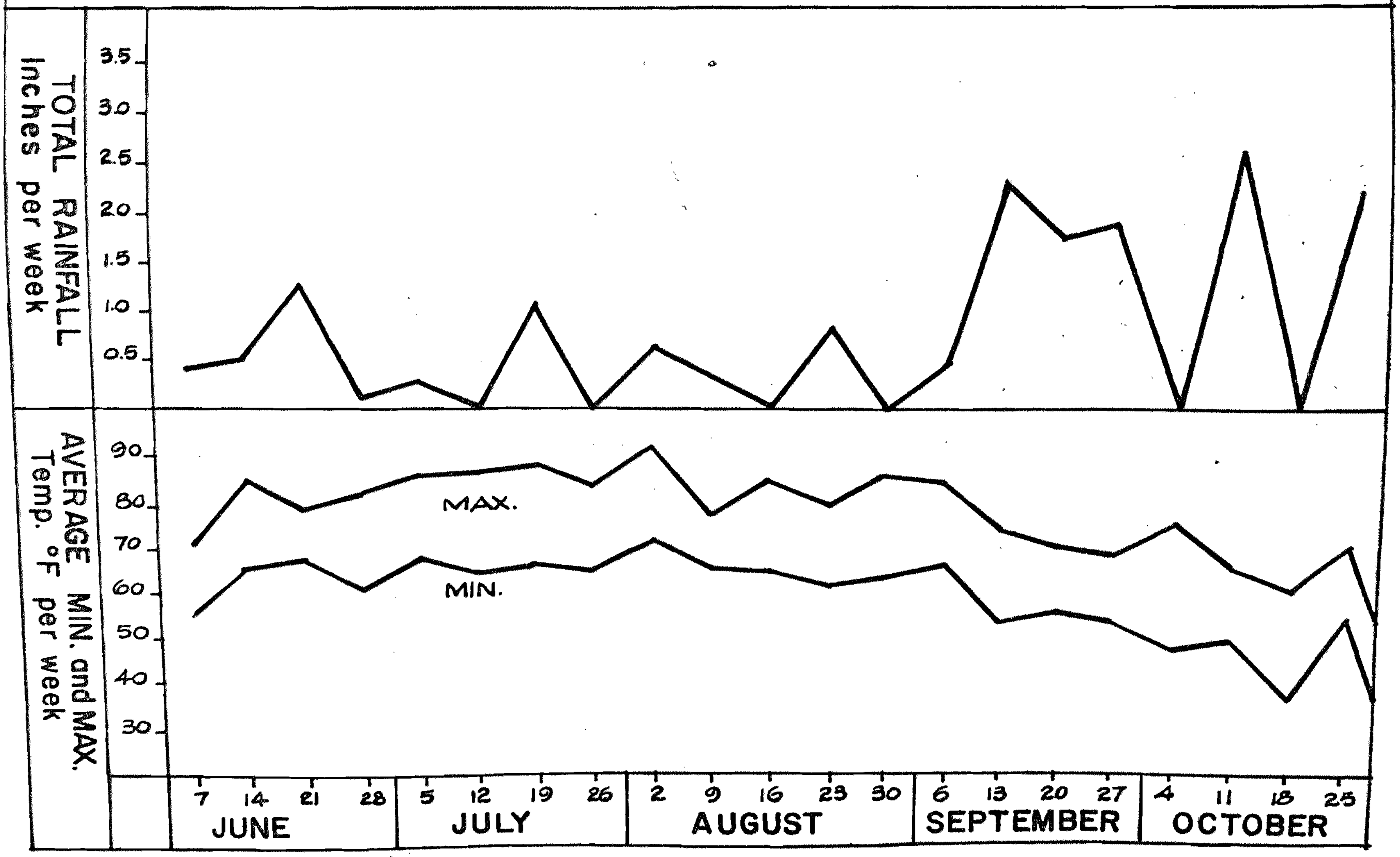
The following treatments produced results with approximately the same significance: 1) interaction between cultivation, burning, and the herbicide, 2) burning, 3) interaction between cultivation and the herbicide.

Other than cultivation, burning was the most effective single method of weed control. This was due partially to the fact that burning was injurious to the weedy plants. Poa pratensis is particularly sensitive to burning because the early spring growth which has produced young grass shoots are damaged by burning (Hadley and Kieckhefer, 1963).

Other advantages to burning which are given by Mayer and Poljakoff-Mayer (1963) are the removal of vegetation which improves light and aeration, removal of competition for space, light, and nutrients between the seedlings which are establishing themselves and the existing weedy plants, and the destruction of accumulated inhibitors present in the soil cover.

The disadvantage of using fire as the only method of weed control is the reduction in soil moisture due to increased soil temperature in the burned plots. Ehrenreich (1957) stated that this occurred because of the increased transpiration from the earlier development of the vegetation and a higher rate of evaporation from the soil surface caused by the higher soil temperature and increased exposure. This disadvantage may have been reduced in this study by the abundant rainfall of the 1970 growing season (Fig. 16).

FIGURE 16. Total rainfall and the min.-max. temperature for the week preceding the date. (Des Moines Weather Bureau)



The interaction between cultivation, burning and the herbicide, and the interaction between cultivation and the herbicide may be considered similar. This is because of the effects of burning being negated by turning under the burned soil surface to a depth of 6-8 inches.

The results of these interactions are similar and may be viewed from two positions. The positive effects of cultivation were reduced by the application of the herbicide or the effectiveness of the chemical action of the herbicide was increased by cultivation.

The action of the inorganic herbicide, ammonium sulphamate, produces unfavorable effects which may have led to the reduction in the effectiveness of cultivation. These unfavorable effects are, the prolonging of the dormancy of plants, the production of soil sterility, and destruction of cell protoplasm by the toxic ammonium ion (Audus, 1964). Mayer and Poljakoff-Mayer (1963) also state that herbicide when applied directly to seeds may prevent their germination. This would have been possible since the seeds were sown by broadcasting and then covered with approximately one-half inch of the herbicide-treated soil.

The advantages of cultivating before application of the herbicide, which would increase the effectiveness of the herbicide, are stated by Audus (1963) to be: 1) causing of the weed seeds to germinate increasing thereby the effectiveness of the herbicide, 2) exposing roots and stolons to effects of the herbicide, and 3) lowering of the reserves of deep-rooted weeds by repeated cultivation.

The interaction between burning and the herbicide was significant, but not as significant as burning alone. This is misleading since prairie grass plants germinated in the plot with interaction between burning and the herbicide whereas none germinated in the plot treated only by burning. Neither of these treatments destroyed the weedy grass sod, but merely reduced the surface vegetation. The herbicide may prove to be the most important as a long term factor. The mechanical damage to the vegetation by fire should have increased the effectiveness of the herbicide. The burned plot had a complete re-growth of weedy grasses by the summer of 1971 and the plot with interaction between burning and the herbicide has a reduced growth of weedy vegetation and bare spots on the soil surface where seed could germinate.

The interaction between cultivation and burning was significant. However, as previously stated the effect of burning was lost with the cultivation of the surface soil under to a depth of 6-8 inches. Therefore the significance of this interaction is primarily due to cultivation.

The application of the herbicide did not produce significant results. This may be the result of the herbicide causing a decrease in the germination of the seed, and also sterility of the soil. The immediate effect of the herbicide appears to be unfavorable, but the long term effects appear to be favorable. In the summer of 1971 after overwintering, more prairie plants seem to be growing in the herbicide treated plots, which have a marked reduction in weeds, as compared to the non-herbicide treated plots. This effect is particularly noticeable in the plots which were cultivated in addition to having the herbicide applied to the soil.

SUMMARY

1. Five species of prairie grass were sown in plots treated with one of the following methods of weed control: cultivation, burning, herbicide, cultivation and burning, cultivation and herbicide, burning and herbicide, and cultivation, burning, and herbicide. Effects of the weed control treatments on the germination and establishment of these species of grass were observed.
2. There was a significant difference in germination and establishment of the prairie grasses according to the method of weed control.
3. Cultivation produced the most significant difference in the germination and establishment of the prairie grasses.
4. The most significant difference in the germination and establishment of the prairie grasses produced by an interaction between two methods of weed control was cultivation and herbicide.

5. The herbicide ammonium sulphamate did not produce significant results as an effective method of weed control. However, further study of this warranted because of its significant interaction with cultivation.
6. Burning produced a significant difference in the germination and establishment of the prairie grasses. However, this was primarily due to the interaction with other methods of weed control since none of the species of prairie grasses germinated in the plot that was burned.
7. This study indicates that cultivation as a prerequisite to sowing would improve the germination and establishment of prairie grass. This conventional method of weed control in agriculture, could be used effectively to establish prairie along roadsides, to restore land in soil bank, to renovate commercial and private wastelands, for landscaping, and for historical and esthetic value.

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